STRONG NEED FOR IMPROVED ULTRASONIC STANDARDS FOR INSPECTION OF ARTILLERY SHELL METAL BODIES

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ABSTRACT

Ultrasonic standards for artillery shells are made by machining grooves into inert projectile bodies. Current standards are difficult to design and build and do not realisticly simulate manufacturing defects. This poster paper will discuss the design process and use of ultrasonic standards and will describe some of their current limitations.

This poster paper describes an Army problem concerned with the design and use of ultrasonic standards for artillery shell inspection. Three aspects of this problem will be addressed: (1) How standards are designed, (2) How standards are used, and (3) Problems with current standards.

(1) How standards are designed:

During the initial design phase, a stress analysis of the projectile for launch and rough handling is made and the critical defect sizes and locations are determined from fracture mechanics. The upper part of Figure 1 shows a stress profile for the M549 155mm Projectile under launch conditions. Fracture mechanics is then applied to determine critical crack sizes. Critical crack sizes for certain locations in the M549 Projectile are shown in the lower section of Figure 1.

Ultrasonic standards for artillery shells are made by machining grooves into inert projectile bodies. In order to determine the required depth of these grooves (for a fixed length) the ultrasonic response from cracked shells and from grooves is compared (Figure 2). From this study, groove depths are determined that give reflection amplitudes nearly equivalent to those expected for "ideal" critical cracks. Because the data (Figure 2) shows a great deal of scatter, the worst case ratio of groove to crack response is chosen in order to be conservative.

The final design of the standards is determined by such factors as the size and location of the critical defects, the correlation study for groove and crack response, machining limitations and cost considerations. Figure 3 shows the placement of the grooves in two standards for the M549 Projectile.

(2) How standards are used:

The inspection procedures and the proper use of the standards are described in the Technical Data Package. A page from such a document is shown in Figure 4. The critical function of the ultrasonic standards is to set the accept/reject thresholds for the ultrasonic inspection. The accept/reject threshold is set at the level of the reflected signal from the standard. This means that the standards play a critical role in determining the overall rejection probability of the ultrasonic inspection.

Ultrasonic standards are also used for setup and calibration of the ultrasonic equipment. Periodically, the inspection system will use the standards to check proper alignment of transducers and threshold level settings. Figure 5 shows an example of a recent ultrasonic inspection station for the M549 Projectile.

(3) Problems with current standards:

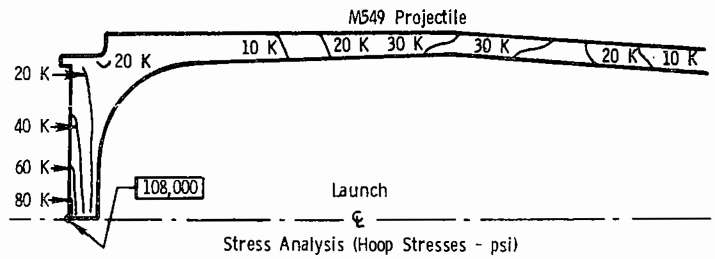
The design of current standards is a difficult and costly process. As previously mentioned, standards are made by machining grooves into inert warheads. Unfortunately, as pointed out by expensive empirical studies, there is generally a poor correlation between the ultrasonic response from grooves and real cracks. Therefore, current standards do not closely simulate real cracks. This complicates the design process because it is difficult to determine the proper groove depth and length that best represents the response from a critical defect. Generally, the worst case ratio of groove to crack response is taken in order to be reasonably safe. This approach, however, may be overly conservative and may lead to an unnecessary increase in the false rejection rate (rejection of good shells).

Current standards are expensive to build because machining grooves to tight specifications is difficult and time consuming. Using the best technology available, it is still not possible to machine two standards with identical ultrasonic response. Each standard is truly "unique."

In conclusion, standards are needed that are less costly to design and build and, yet, are more realistic in simulating manufacturing defects.

Acknowledgement: The author would like to thank Mr. Mark Weinberg, ARRADCOM, Dover, New Jersey, for providing some of the Figures shown in this poster paper

Critical defect sizes are determined from stress analysis and fracture mechanics.



Fracture Mechanics

● THRU-THE-THICKNESS CRACK

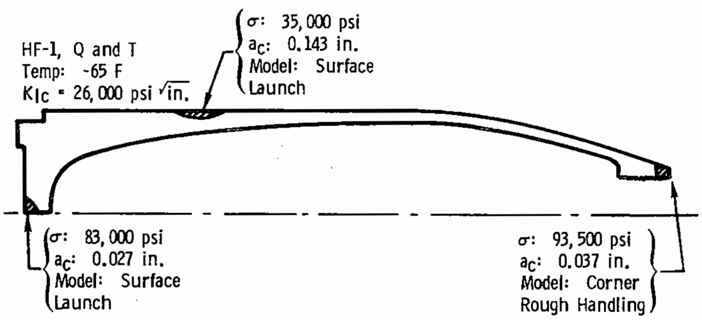
$$a_c = \frac{1}{\pi}\left(\frac{K_{IC}}{\sigma}\right)^2\left[1-\frac{1}{2}\left(\frac{\sigma}{\sigma_{ys}}\right)^2\right]$$

● EDGE CRACK

$$a_c = \frac{1}{\pi}\left(\frac{K_{IC}}{1.1\,\sigma}\right)^2$$

● SEMI-CIRCULAR CORNER CRACK

$$a_c = \pi\left(\frac{K_{IC}}{2.56\,\sigma}\right)^2$$



Critical Crack Sizes for Certain Locations

Figure 1. Stress analysis and critical crack sizes for M549 projectile.

Standards consist of grooves machined into an inert warhead. Correlation between ultrasonic response of grooves and real cracks is needed.

Sample	Zone	Equivalent Groove Depth	Actual Measured Crack Depth	Groove/Crack
1	Ogive	0.020	0.006	0.30
5	Ogive	0.020	0.020	1.00
10	Ogive	0.030	0.050	1.67
29	Ogive	0.030	0.060	2.00
32	Bourrelet	0.020	0	0
34	Ogive	0.020	0.050	2.50
40	Bourrelet	0.020	0	0
46	Ogive	0.010	0.040	4.00
68	Ogive	0.020	0.040	2.00
74	Bourrelet	0.020	0	0
93	Bourrelet	0.010	0	0
102	Ogive	0.030	0.060	2.00
176	Bourrelet	0.010	0	0

Data taken from ARRADCOM Report QAR-Q-013, "Defect Correlation Analysis for Fixed Channel Ultrasonic Inspection System for Warhead, 155MM, M549A1," R. Scott, April 1979.

Figure 2. Destructive analysis of cracked shells to correlate groove and crack response.

The final standard design is determined. Position, orientation, depth, length, and machining characteristics of each groove is specified.

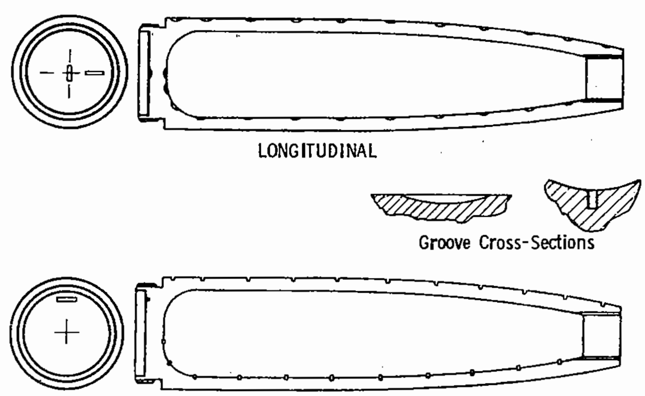


Figure 3. Ultrasonic inspection standards.

Included in a Technical Data Package is a description of the required inspection procedures. This document specifies the NDT methods to be used, the design of the standards, and the inspection equipment parameters. Standards are used to set the accept/reject thresholds, which determine to a great extent how reliable the inspection will be.

2.5 THE SYSTEM SHALL ULTRASONICALLY INSPECT THE ENTIRE PROJECTILE IN BOTH LONGITUDINAL AND CIRCUMFERENTIAL DIRECTIONS. INSPECTION SENSITIVITY MUST BE ADEQUATE TO REJECT ALL SLOTS IN ULTRASONIC INSPECTION STANDARDS.

2.6 THE SYSTEM MUST CONFORM WITH ALL PLANT, MUNICIPAL, STATE AND NATIONAL CODES AND SAFETY REGULATIONS INCLUDING OSHA REGULATIONS.

2.7 THE SYSTEM SHALL PROVIDE A MEANS TO AUTOMATICALLY MARK A "U", AS SHOWN ON BODY, PREFORM DWG 9323969 ONLY ON ACCEPTED BODIES. REJECTS SHALL BE PERMANENTLY STAMPED AND SEGREGATED AND NOT ALLOWED TO RE-ENTER THE PRODUCTION LINE.

UNOFFICIAL

3. A TANK SHALL BE PROVIDED WHICH SHALL: **NOT FOR PRODUCTION**

3.1 BE FABRICATED OF CORROSIVE RESISTANT MATERIALS. DISSIMILAR METALS SHOULD NOT BE USED TO AVOID ELECTROCHEMICAL REACTIONS. JUN 26 1978

3.2 BE LARGE ENOUGH TO ALLOW EASY INSERTION AND REMOVAL OF THE BODY AND TO CONTAIN THE SUPPORT FIXTURE AND THE TRANSDUCERS WITH THEIR MANIPULATORS, WITH SUFFICIENT ROOM FOR CONVENIENT ADJUSTMENT OF THE TRANSDUCERS.

STANDARD TANK MUNITIONS

TITLE	SIZE	CODE IDENT NO.	
ENVELOPE DRAWING ULTRASONIC INSPECTION EQUIPMENT OF BODY FOR PROJECTILE, 105MM, HEAT-T, M456A2 METAL PARTS	A	19200	9323972
	77-09-07	REVISION LEVEL —	SHEET 2

SARPA Form 1153, Sep 74

Figure 4. Page from a technical data package.

Standards are used to set up and calibrate the ultrasonic inspection equipment. Periodic calibration of the equipment is specified in the Technical Data Package.

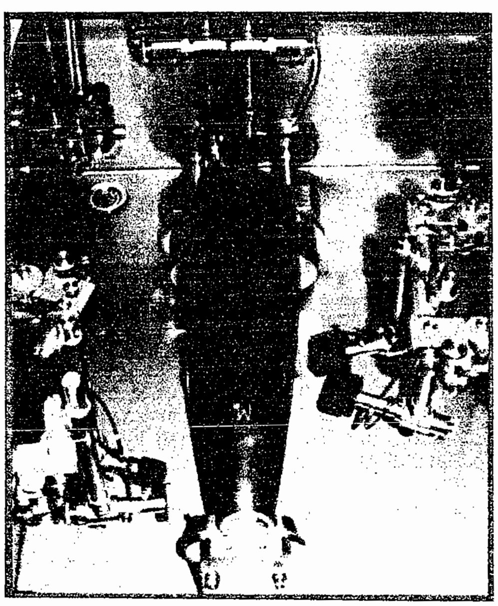


Figure 5. Example of ultrasonic shell inspection system.